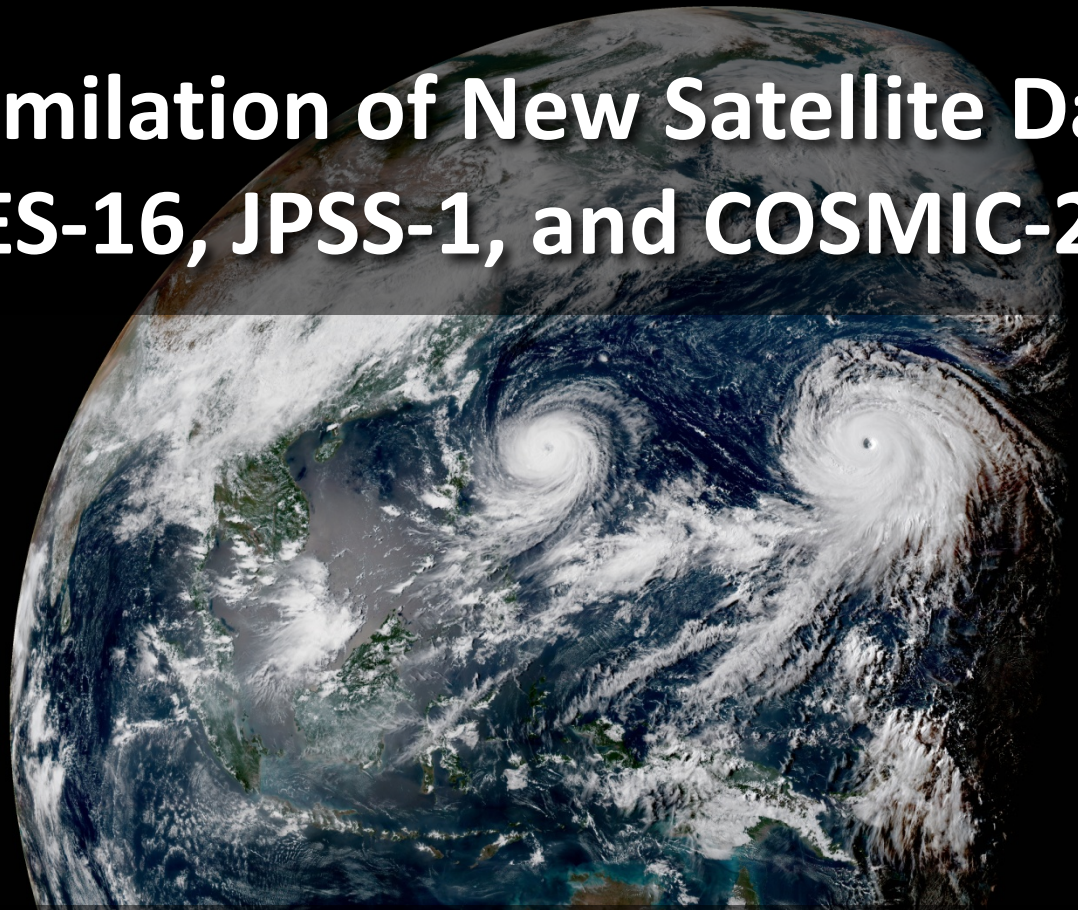
Assimilation of New Satellite Data: GOES-16, JPSS-1, and COSMIC-2



Benjamin T. Johnson (UCAR @ JCSDA)
Andrew Collard (IMSG @ NOAA/NCEP/EMC)
Biljana Orescanin (RTi @ JCSDA), Ling Liu (AER @ JCSDA)
Lidia Cucurull (NOAA ESRL/AOML)
James Yoe (NOAA/NWS/JCSDA)
Thomas Auligné (Director, JCSDA)

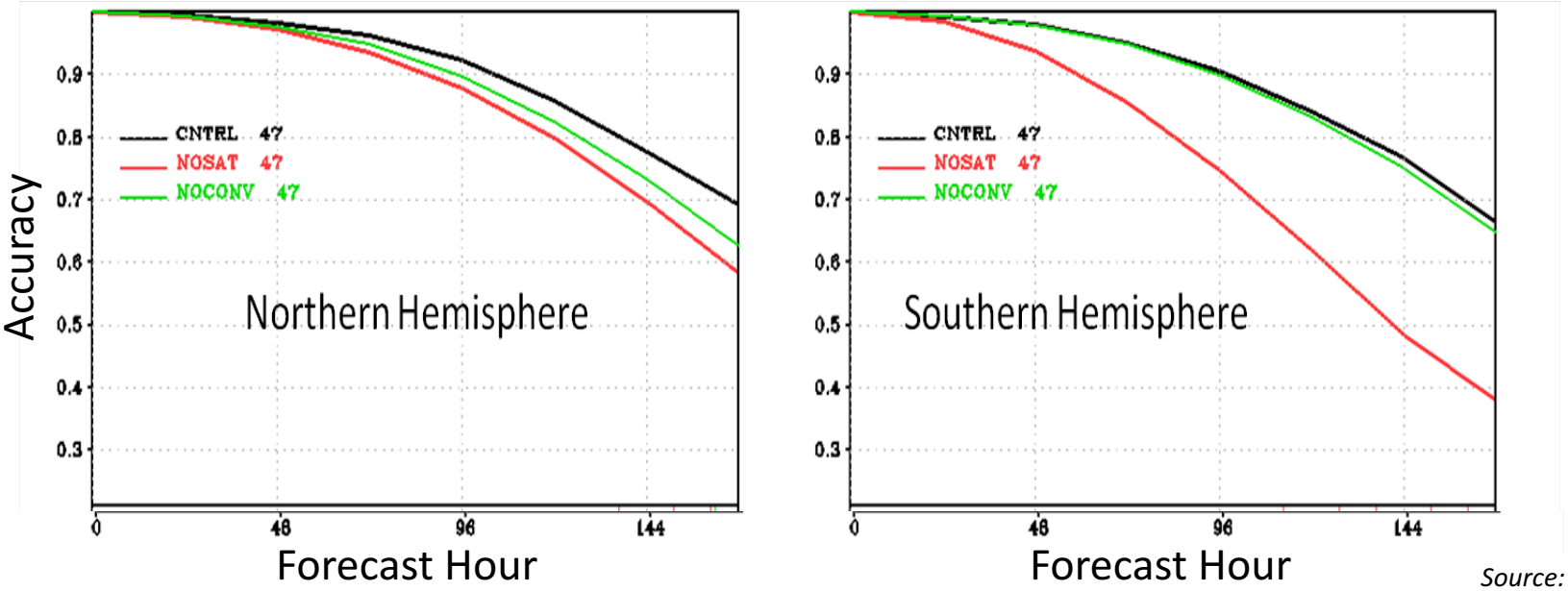
8th NOAA Testbeds and Proving Ground Workshop, April 25-26, Kansas City, MO

JCSDA Goal: Improve and Accelerate
Satellite Data Assimilation

Socio-economic benefit of NWP forecast: estim. $100B-$1T per year *(Riishojgaard, 2014)*

Contributions to NWP forecast: Initial Conditions = Model *(Magnusson and Källen, 2013)*

Initial Conditions: Satellites dominate global impact of observations



Source: Jung (2012)

General DA procedure for new sensors

- Develop requirements: Which products to assimilate? Radiances? AMVs? Other retrieved parameters?
- Operational system -> to Research teams (O2R)
- Pre-launch Science:
  - Readiness Action Plan (RAP)
  - DA using Proxy Data or Simulated Data
  - DA using similar sensors
  - OSSE
- Pre-launch Technical:
  - data ingest and packaging: e.g., BUFR
  - thinning/superobbing
  - QC updates based on
  - “reader” software
- Post-launch (after check-out / cal+val):
  - Update pre-launch assumptions, error characterization, QC, etc.
  - OSE / FSOI
- Update Operational system with new research (R2O)

GOES-16 ABI Readiness Planning

Ling Liu (AER/JCSDA), Andrew Collard (EMC),
Benjamin Johnson (UCAR/JCSDA), Thomas Auligne (JCSDA)

Goals:

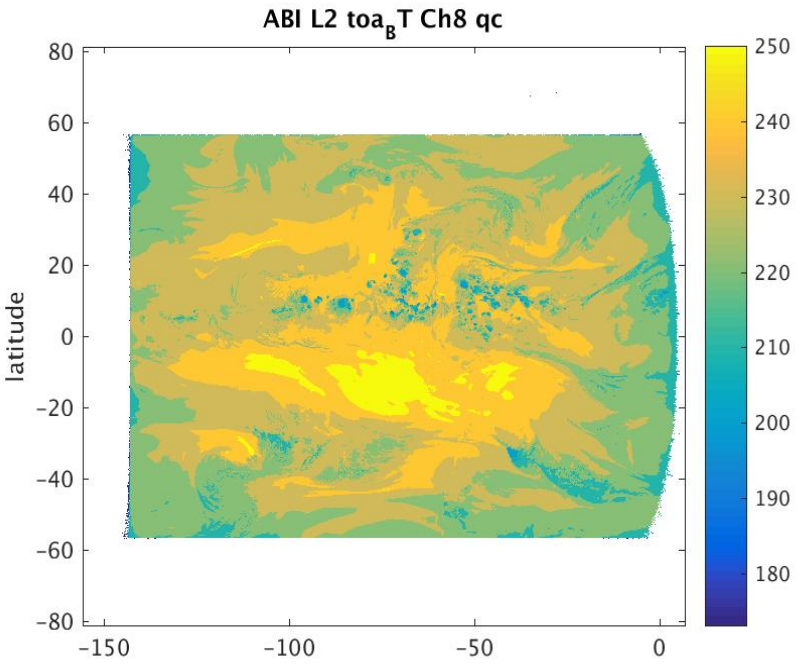
- Assimilate Himawari AHI radiance data into GSI/GFS;
- Evaluate the effectiveness of channel selection
- Support the transition to operations of AHI L1B radiance assimilation
- Conduct preliminary assessments of GOES-R L1B ABI radiance observations in the GSI/GFS

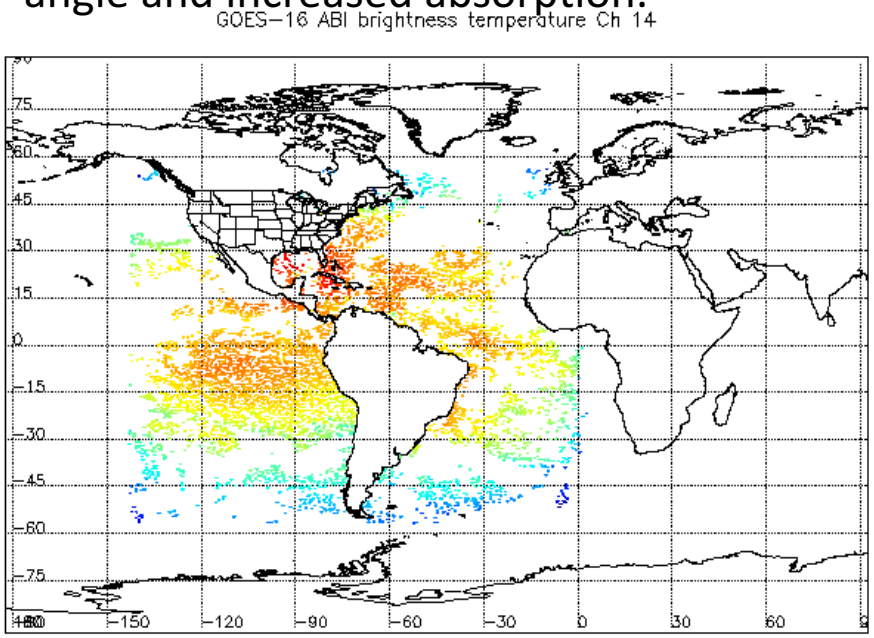
Research Approach:

- Clear-sky AHI radiance assimilation and impact assessment
- All-sky AHI radiance assimilation
- Real-time GOES-16 ABI full-disk radiance ported into GSI.
- Maps of ABI observations of brightness temperature for Channel 7-16 have been plotted. Also shown is the initial O-B with filtering.

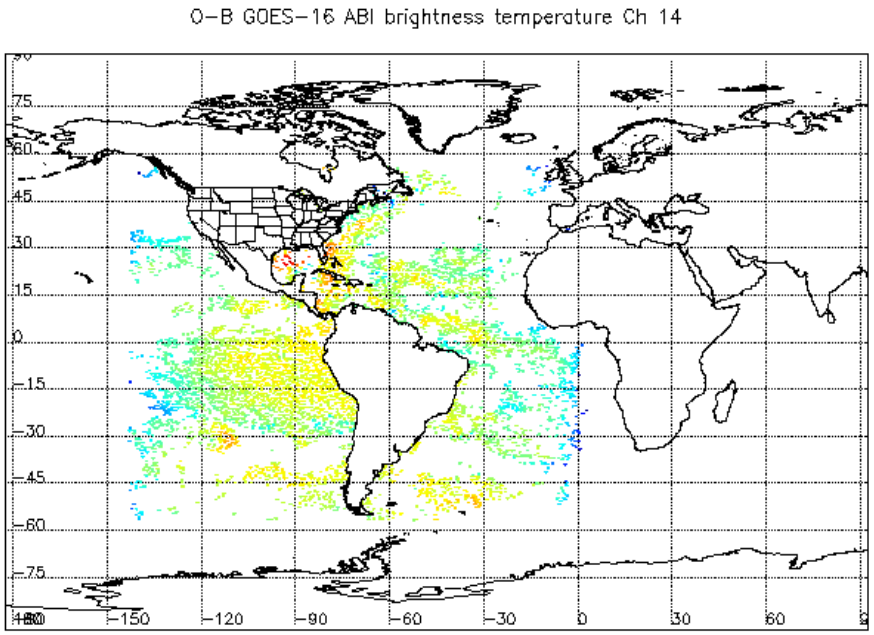
JCSDA GOES-16 ABI assimilation in GSI:

- Higher brightness temperature at tropical sub-tropical area due to higher scan angle for water vapor channels .
- Surface temperature channels have consistent higher brightness temperatures over tropical area.
- Plots shown are rather patchy due to rain filter applied in the analysis.
- Edges of these plots show very low brightness temperature which is caused by the lower view angle and increased absorption.





Channel 14



Ch 14. O-B

L. Liu (AER / JCSDA)

JPSS ATMS/CrIS Assimilation Efforts At NOAA/EMC (A. Collard and DA team)

- JPSS-1 will launch in Q4 FY 2017.
- At NCEP we have plans to assimilate
  - Cross-track Infrared Souder (**CrIS**)
  - Advanced Technology Microwave Sounder (**ATMS**)
  - Ozone Mapping and Profiler Suite (**OMPS-N**)
- These instruments are currently flying on S-NPP and we currently assimilate both CrIS and ATMS operationally.

Advanced Technology Microwave Sounder (ATMS)

- S-NPP ATMS :
  - all channels except for Ch 15 which affected by the model top.
  - closely follows clear sky AMSU-A and MHS, but AMSU-A like channels are remapped
  - The impact of ATMS on the forecast skill is close to neutral: reasonable considering the number of similar observations in the PM orbit.
- *Assimilation of ATMS on JPSS-1 will closely follow the configuration of S-NPP*
  - All-sky DA upgrade for ATMS in the near future, but most likely not in the initial implementation of JPSS.

S-NPP CrIS Data Assimilation Configuration

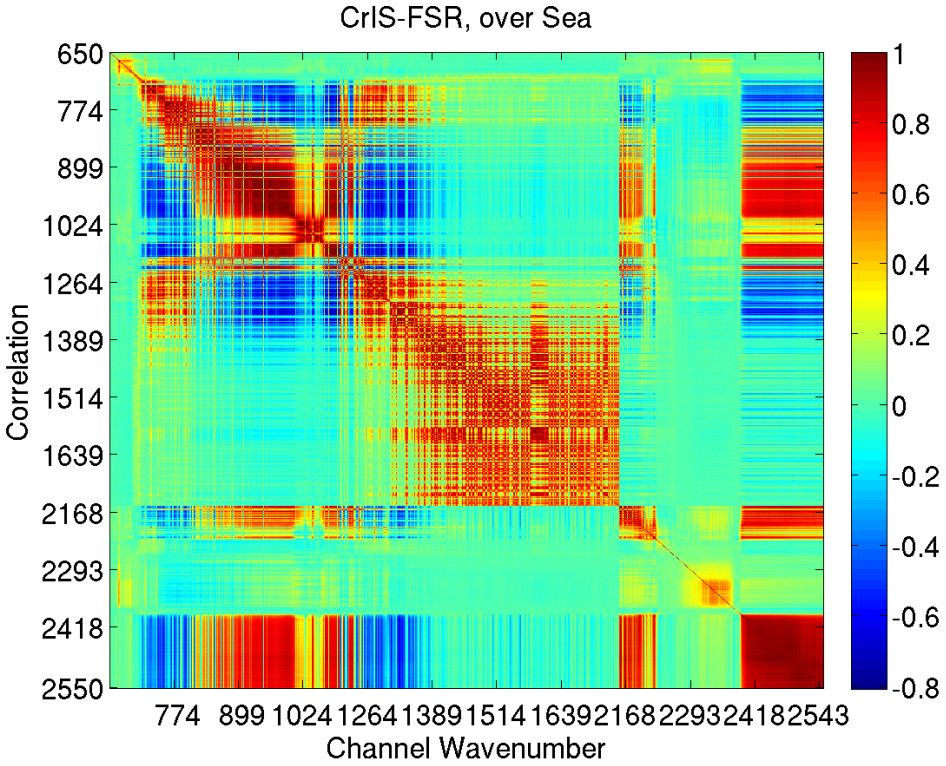
- We receive a subset of 399 channels (Gambacorta et al., 2013) in BUFR format.
- We assimilate those channels designated for temperature, cloud, CO_2 and surface that do not suffer from solar contamination. This totals 84 channels from 672.5cm^{-1} to 1095.0cm^{-1}.
  - This is similar to our IASI channel selection. We hope to extend to include water vapor channels when we switch to FSR for JPSS-1, although the additional impact is likely to be small.
- Forecast impact is small and positive.

JPSS-1 CrIS Data Assimilation

- For JPSS-1 we plan to receive the full FSR spectrum at NCEP – allowing us to be more flexible in our channel selection.
  - We aim to use more of the 15µm CO_2 band channels than is possible with the current selection.
  - We will also make us of channels from the water vapor band.
- A channel selection for NWP has also been produced with Antonia Gambacorta of NOAA-NESDIS

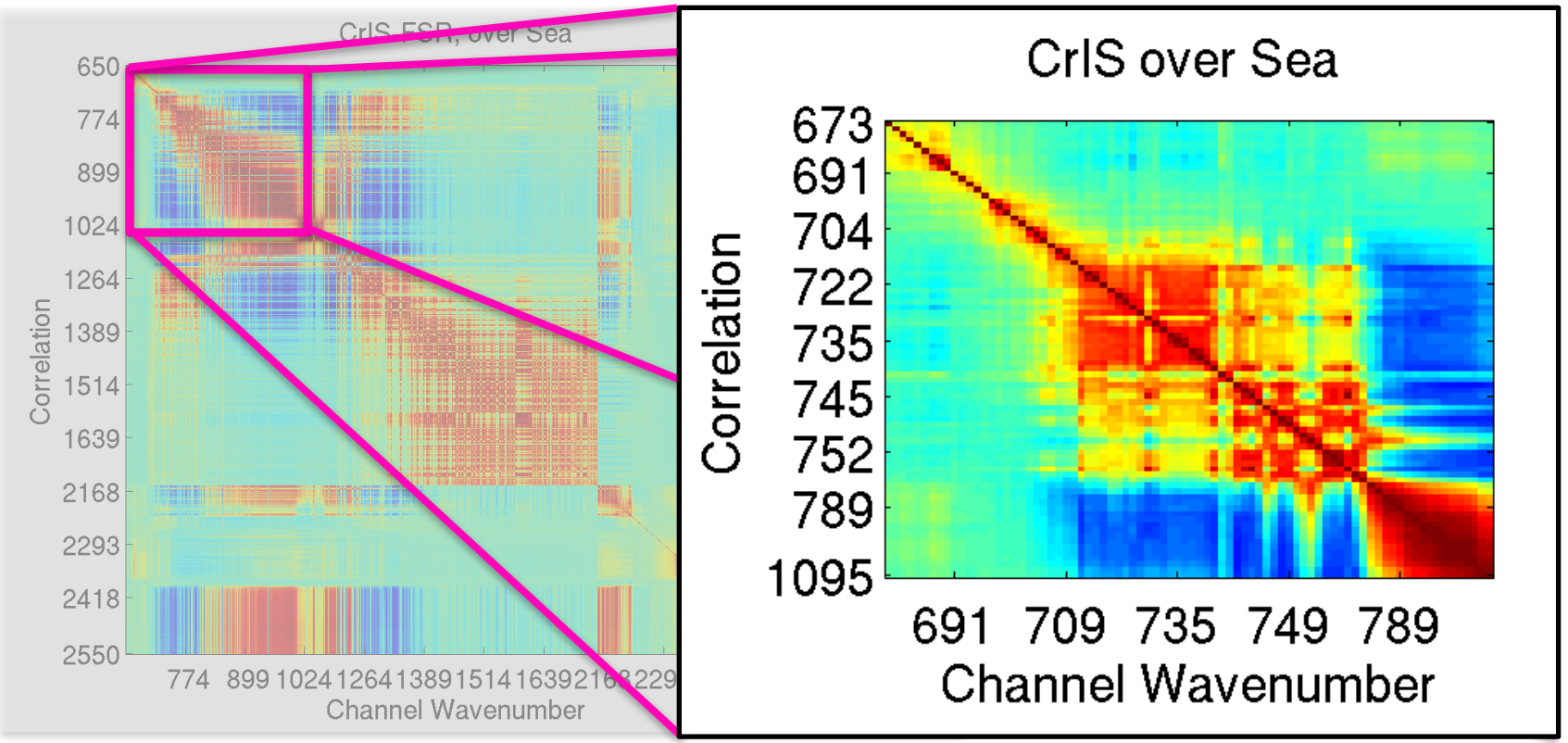
CrIS Correlated Observation Error

- prescribed spectrally-correlated observation errors for CrIS is being tested, possible in JPSS-1 implementation
- Correlated observation errors are important in the water vapor and surface sensitive bands.



CrIS Correlated Observation Error

- The use of apodised radiances introduces correlations. For CrIS using the "correct" correlated observation error is important in the 15 µm (666.7 cm^{-1}) band as otherwise information from the first resonance in the interferogram would be lost.



CrIS Cloudy Radiances

- The assimilation of IASI water vapour channels for cloudy scenes is producing encouraging results (improved fits to MHS radiances and improvements in forecast skill). We are starting similar investigations for CrIS.
- We have also extensively tested cloud-cleared radiances for CrIS, but impact has been very close to neutral.

OMPS-N

- Assimilation of data from the OMPS Nadir sounder from S-NPP will be tested once Version 8 retrieval products are delivered via Product Distribution and Access (PDA).
- It is likely that both S-NPP and JPSS-1 OMPS data will be switched on in the JPSS implementation.

GOES-16 Operational Plans

- GOES-16 was launched in November 2016. It is expected to be placed in its final orbit in November 2017.
- For global NWP, the main impact from GOES-16 is likely to be via the Atmospheric Motion Vectors (AMVs, “Satellite Winds”).
  - We will likely (depending on our assessments) assimilate visible, infrared and water vapour cloud-top winds as well as possibly the water vapour clear-sky winds and the shortwave infrared.

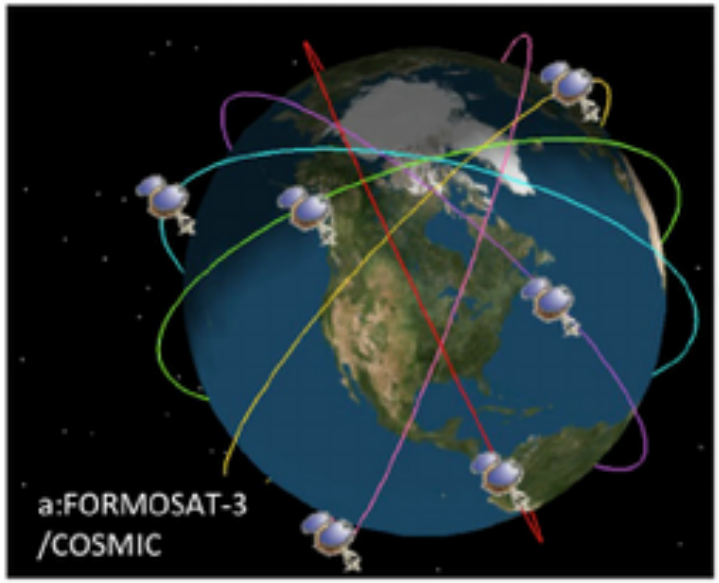
GOES-16 Radiance Assimilation

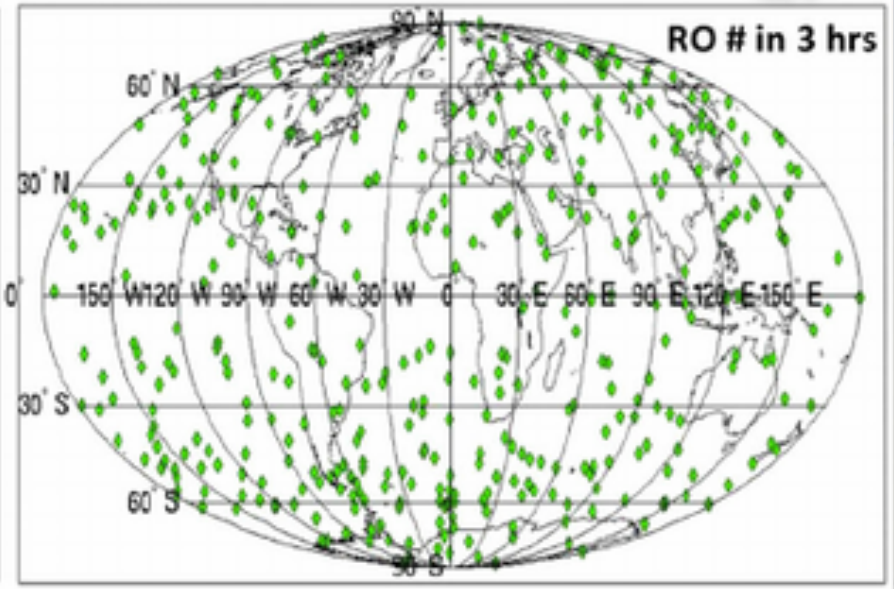
- GOES-16 radiances will be assimilated in the global model at NCEP once a clear-sky radiance product is available.
  - This will be incorporated into an All-Sky radiance product currently being worked on by Heidinger and Wolf.
- Coordination with JCSDA research for all-sky ABI radiance assimilation.

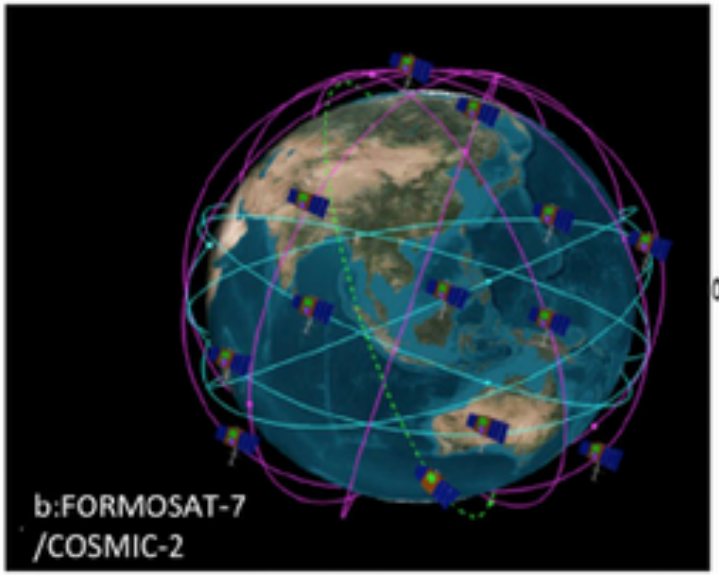
Operational Implementation Overview

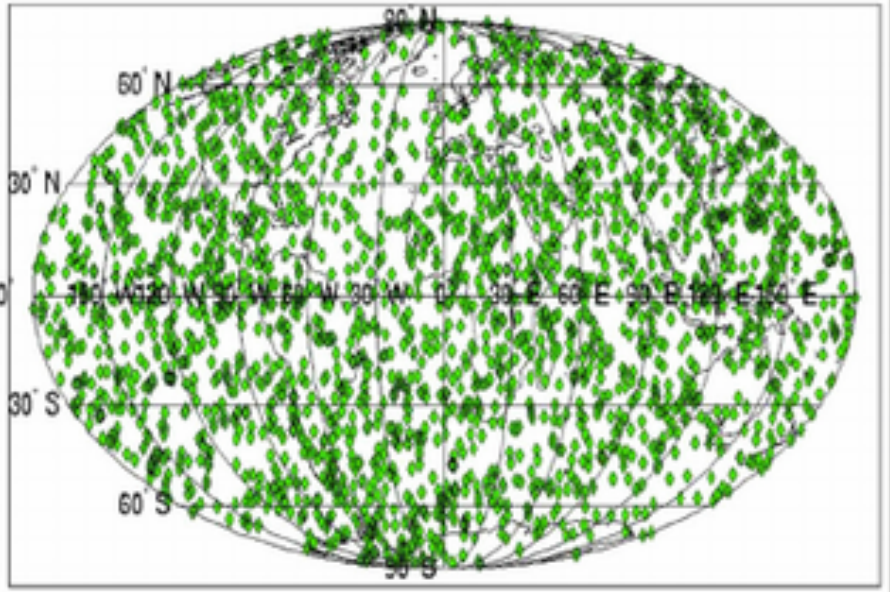
- Implementation of JPSS-1 and GOES-16 data has been scheduled for Q2FY18.
- Exact timing will depend on the availability of the data sources.
- In addition we hope to include additional observing systems including COSMIC-2 (GPS-RO) and TAMDAR (aircraft in-situ observations).

COSMIC-2 Assimilation Efforts (L. Cucurull)



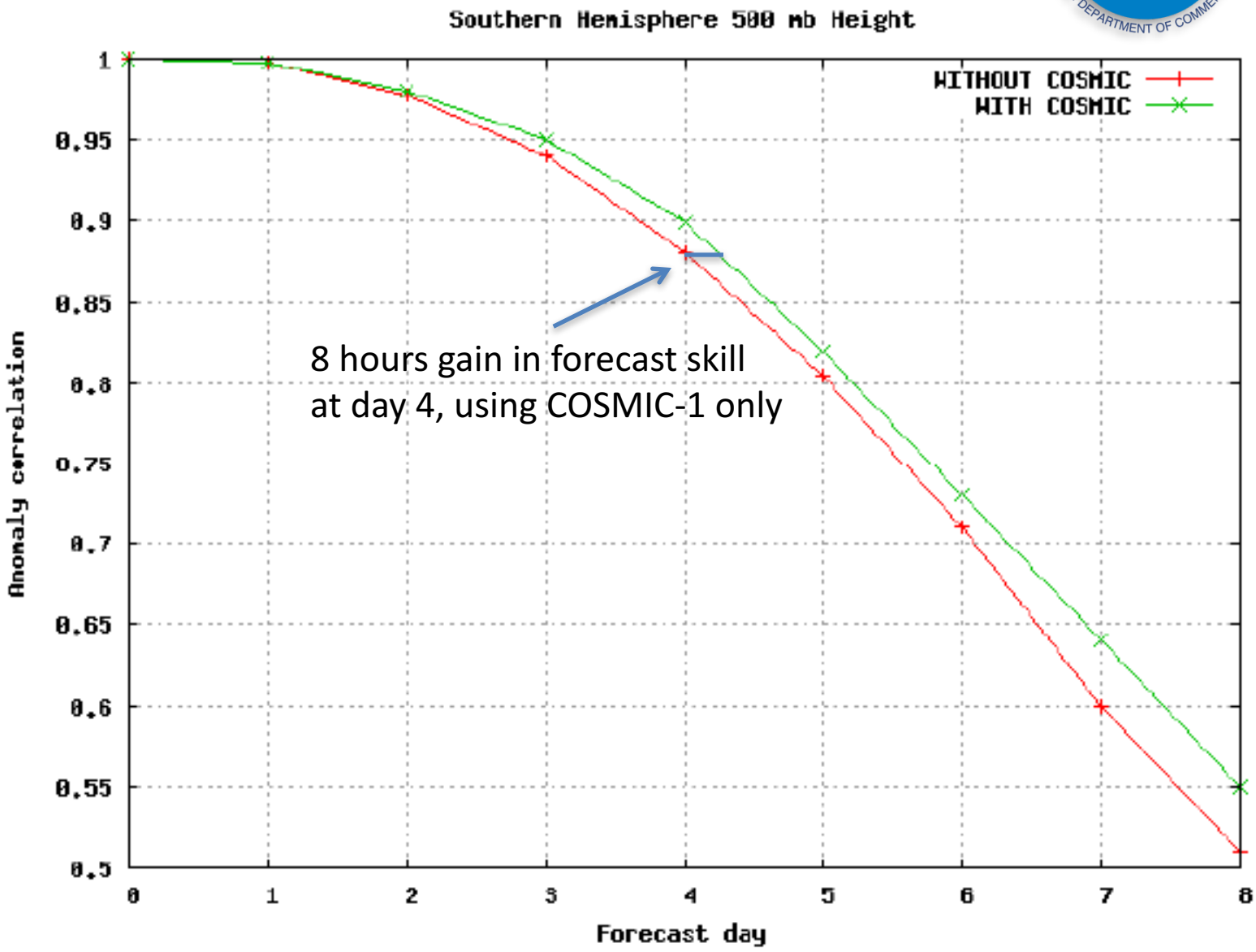






RO Payload
IGOR GPS ~2,000 per day
TriG GPS+ GLONASS >8,000 tropo per day >12,000 iono per day

COSMIC-2 Assimilation Efforts (L. Cucurull)



Cucurull 2010 (WAF)

Assimilation of Radiance Data Over Land (Passive MW and IR sensors)

Biljana Orescanin (RTi/JCSDA), Andrew Collard (EMC), Ben Johnson (UCAR/JCSDA)

Key Goal: Extend and improve quantity and quality of assimilated radiances over land and sea ice for passive MW and IR frequencies.

Purpose : By increasing the number of satellite observations assimilated we expect to see a positive impact on NWP forecast skill.

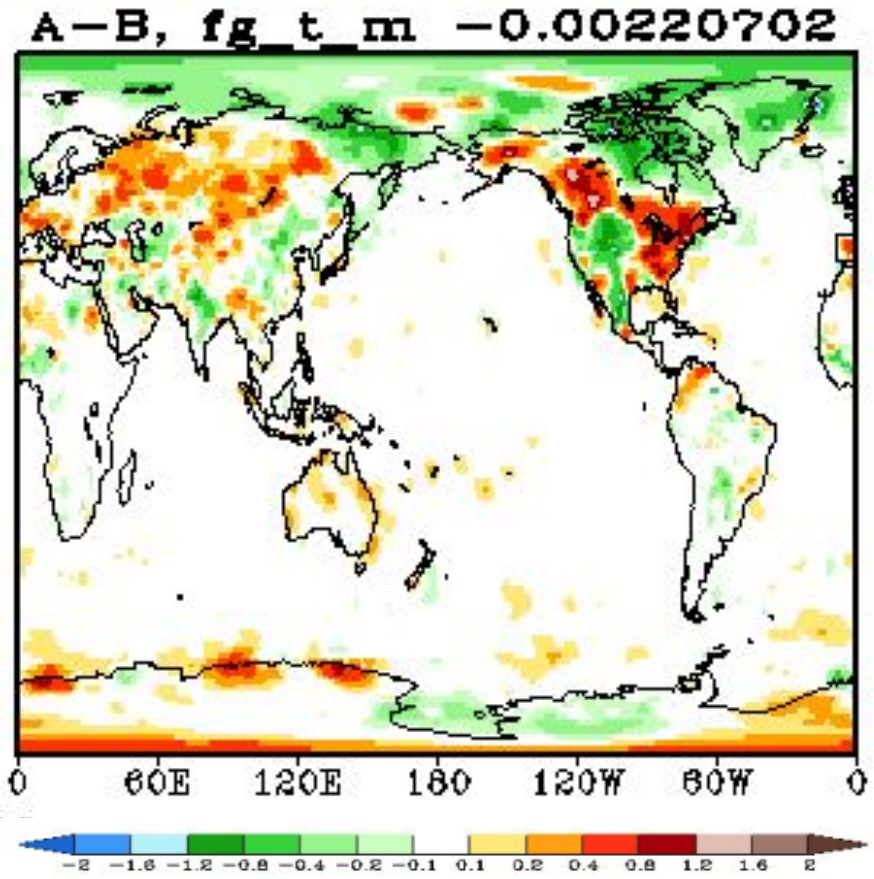
Research Approach:

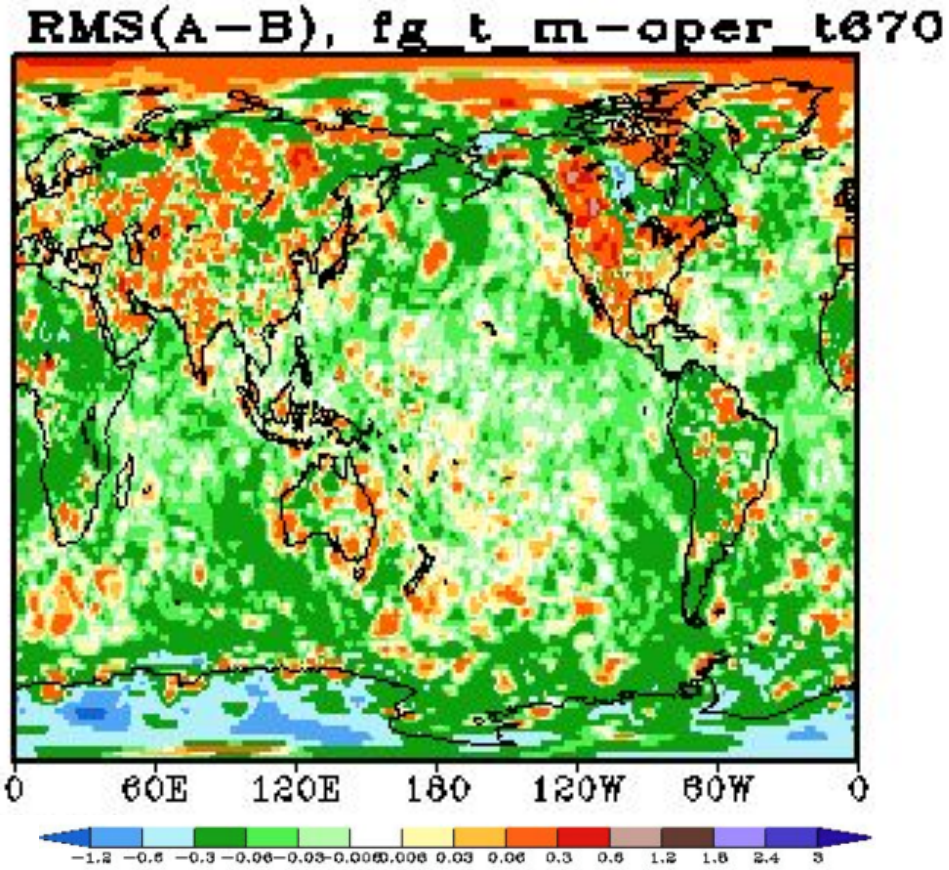
(1) Improve the emissivity first guess; First guess experiments provide us with understanding of system sensitivity to changes in emissivity. Current first guess options explored in 4dEnVar are TELSEM and MIIDAPS.

(2) implement emissivity and “skin temperature” as a control variable into the GSI system

Assimilation of Radiance Data Over Land

- GDAS Analysis Increments maps, Temperature (K), Sigma level 1000hPa, tell how changes made in the system directly affect the analysis.





- Control variable implementation goal is to update emissivity in every assimilation cycle. By doing that our hope is that less observations will be tossed due to bad emissivity.
- Observation System Experiments are performed to quantify the effectiveness of increase in radiance data.

Summary

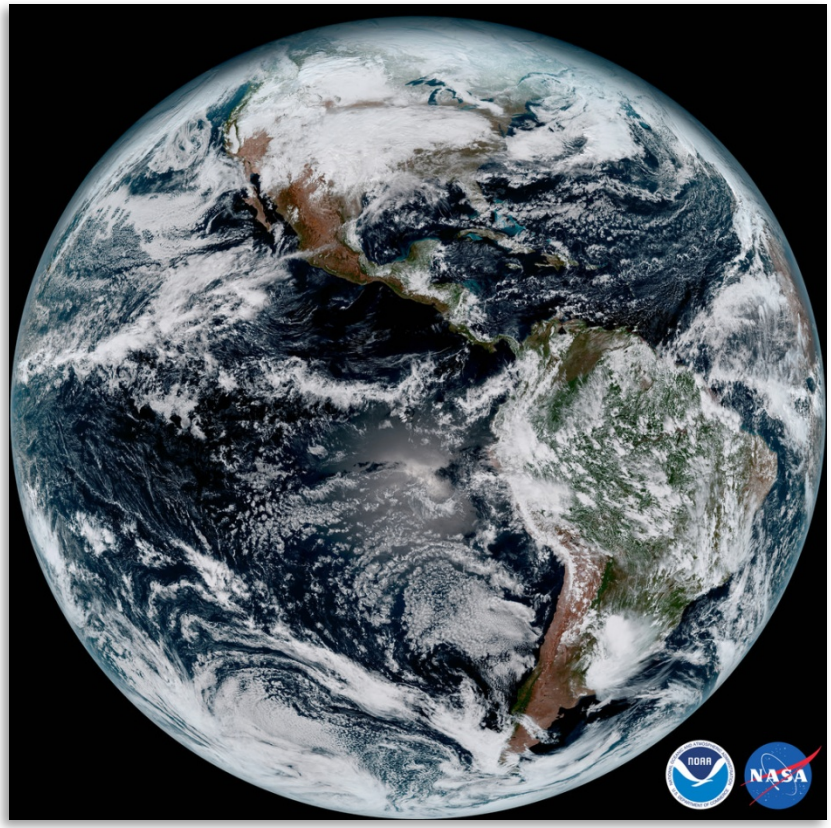
- GOES-16 ABI radiance assimilation in preliminary research stages (clear sky)
  - Himawari AHI 8 data being used as proxy, operational assimilation planned for AHI
- JPSS-1 CrIS to follow existing S-NPP CrIS DA
- JPSS-1 ATMS to follow S-NPP ATMS DA
- JPSS-1 OMP-N: S-NPP OMPS DA waiting on v8, will be implemented in JPSS-1
- COSMIC-2 OSSEs continuing, pre-launch planning (Cucurull)
- Over-land DA: 1st Guess Emissivity improvements, Implementation of emissivity as a control variable in GSI (JCSDA)
- **Questions / comments?**

Email: benjamin.t.johnson@noaa.gov

Additional Slides

GOES-16 ABI Specifications (1/2)

- **Modes of Operation**:
  - **Full Disk:** Hemispheric Coverage of 83° local zenith angle, temporal resolution of 5-15 minutes, and spatial resolution of 0.5 to 2km (*primary interest to global, operational DA*)
    - (full N. Amer. and S. Amer. coverage, centered at equator)
  - **Mesoscale:** 1000x1000km box with a temporal resolution of 30 seconds, and spatial resolution of 0.5 to 2km.
  - **Continental US:** every 5 minutes, providing coverage of the 5000km (E/W) and 3000km (N/S) rectangle over the United States. The spatial resolution is 0.5 to 2km.
  - **Flex Mode:** Full disk scan every 15 minutes, a CONUS every 5 minutes, and two mesoscale every 60 seconds.



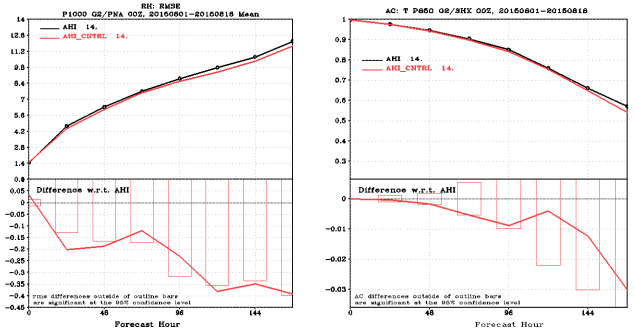
GOES-16 ABI Specifications (2/2)

COMPARISON GOES-R SERIES ABI VS CURRENT GOES

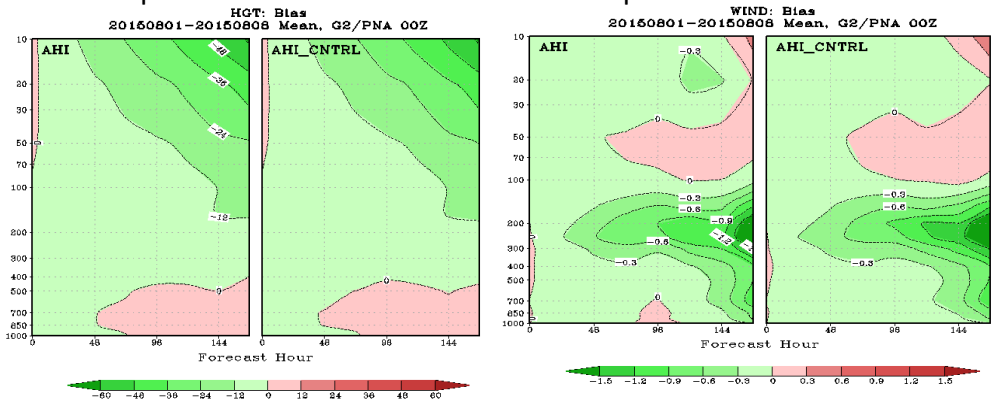
ATTRIBUTE :	ABI	CURRENT GOES IMAGER
Spectral Coverage	16 bands	5 bands
Spatial Resolution		
0.64 µm Visible	0.5 km	~ 1 km
Other visible/near-IR	1.0 km	n/a
Bands (>2 µm)	2 km	~ 4 km
Spatial Coverage		
Full Disk	4 per hour	Scheduled (3 hrly)
CONUS	12 per hour	
Mesoscale	30 or 60 sec	~4 per hour

Instrument	Product Level	Product Short Name	ABI Scene	ABI Mode	Channel	Pixel Size [km]	Average File Size [MB]	Typical maximum size [MB]	24-hr total for one satellite (ABI Mode 3) [MB]
ABI	Level-1b (L1b)	RadF	Full Disk	3, 4	2 (0.64 µm)	0.5	110.3	250.0	11,017
				3, 4	1, 3, 5 (0.47, 0.86, 1.61 µm)	1	24.4	60.0	2,416
				3, 4	4, 6 (1.38, 2.25 µm)	2	6.4	15.0	633
				3, 4	7-16 (3.9, 6.19, 6.95, 7.34, 8.50, 9.61, 10.35, 11.20, 12.30, 13.30 µm)	2	21.6	25.0	2,070

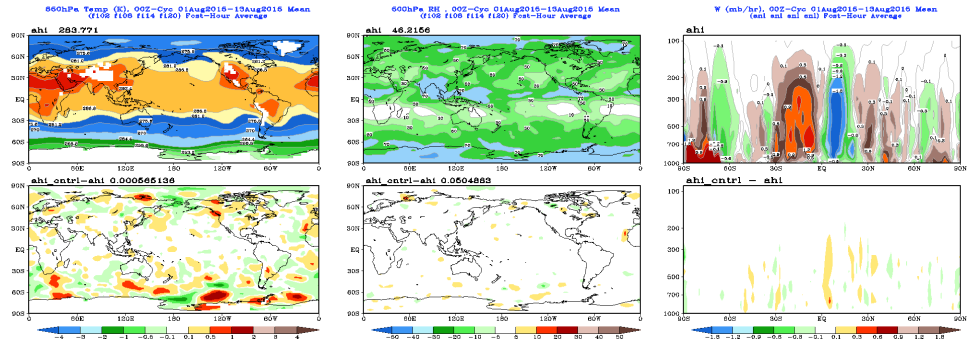
Die-off of relative humidity bias at 1000 hPa between AHI experiment and control run against own analyses. And **Die-off of anomaly correlation of temperature** at 850 hPa between AHI experiment and control run against own analyses both indicate positive impact



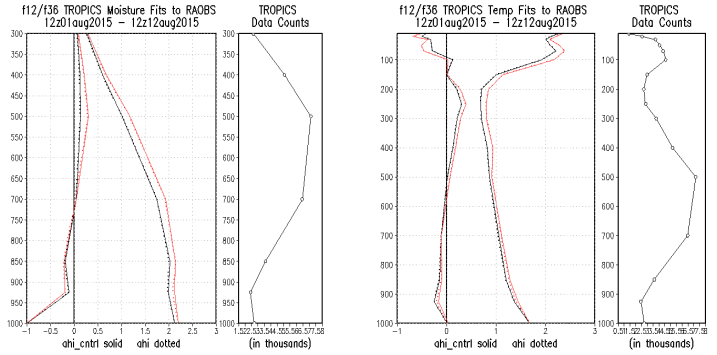
Impact of AHI on geo-potential height at 700 hPa; Two vertical peaks corresponding to Level 400 hPa and surface level indicated by Figure 3.2 (*Ma et al. 2017*) are indicated by the pattern correlation of the temperature and **wind vertical structure** plots



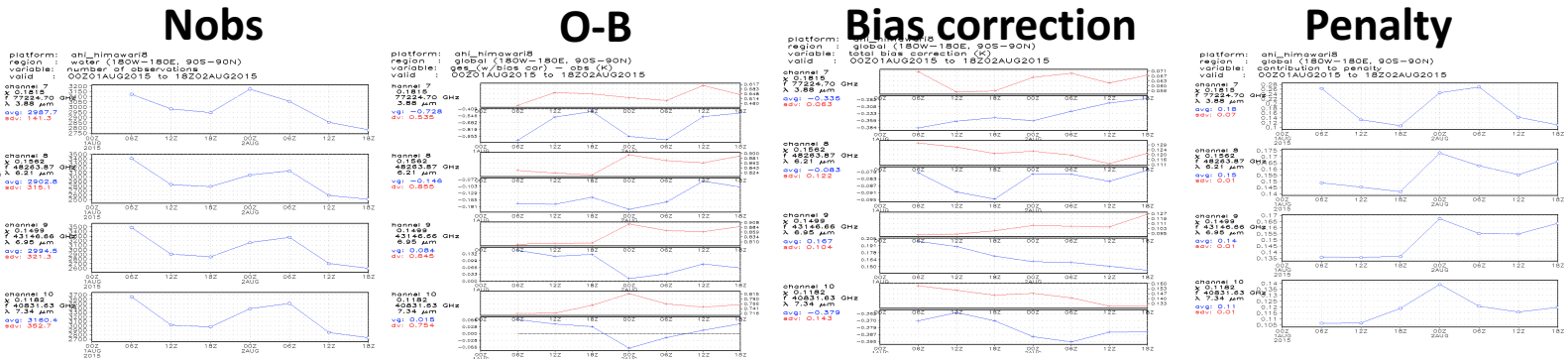
Day 3 foreast on temperature show larger differences at sub-polar between AHI and control experiment compared to the mean forecast. Day 3 forecast of relative humidity shows rather small discrepancy between two experiments at 500 hPa level



Visible improvement of the analysis (black curves) compared to 6 hr forecast (red curves). Assimilating AHI reduces the RMS and bias of tropical, at near-surface level when compared to RAOBS



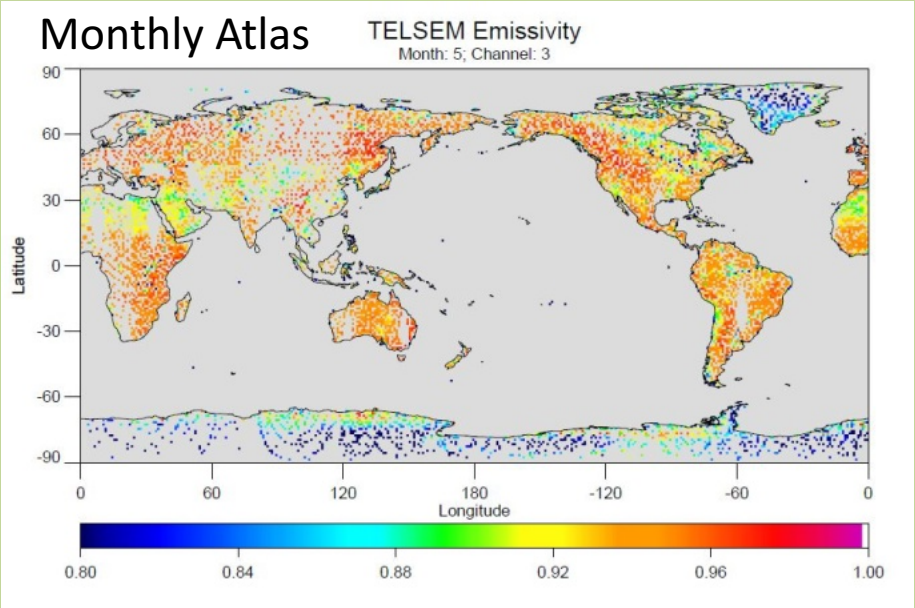
Radiance Monitor tool analysis monitors number of observations, O-B, bias correction and penalty by assimilating AHI



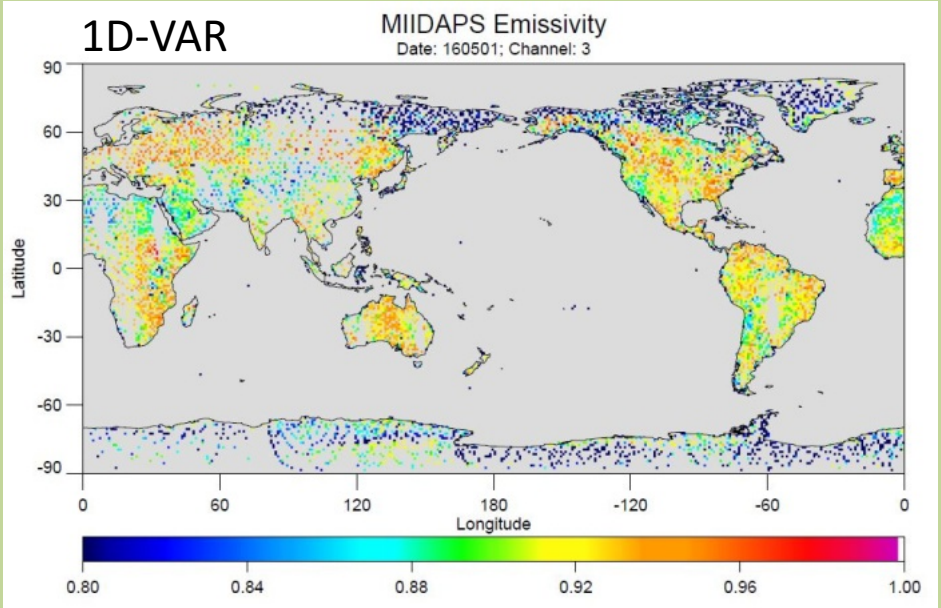
Assimilation of Radiance Data Over Land (Cont.)

- Emissivity maps in respect to different first guess for GSI

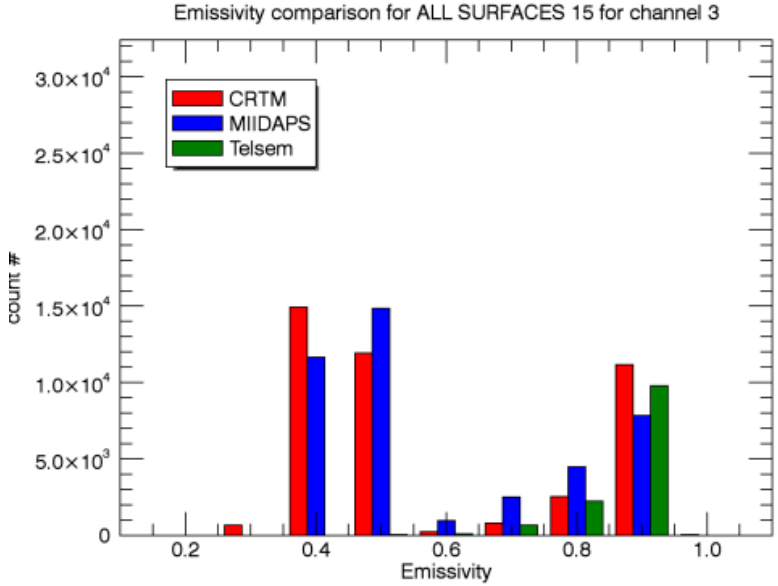
Monthly Atlas

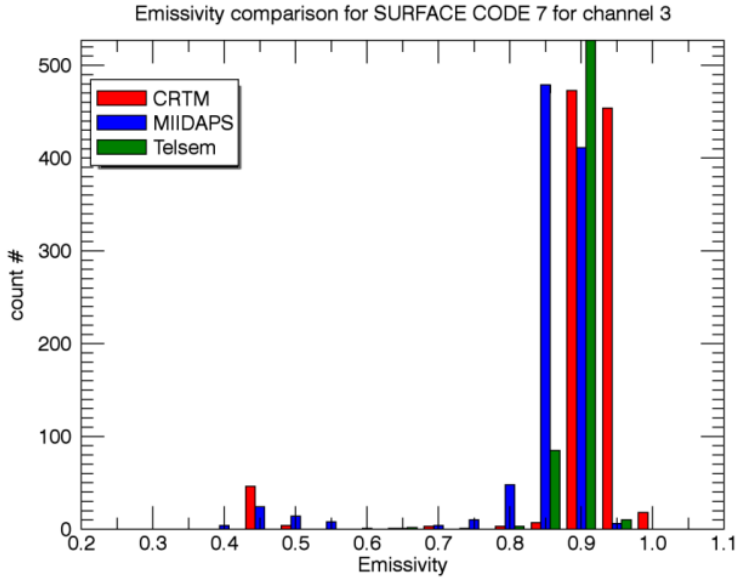


1D-VAR



- Different first guess comparison for arid regions and all surfaces



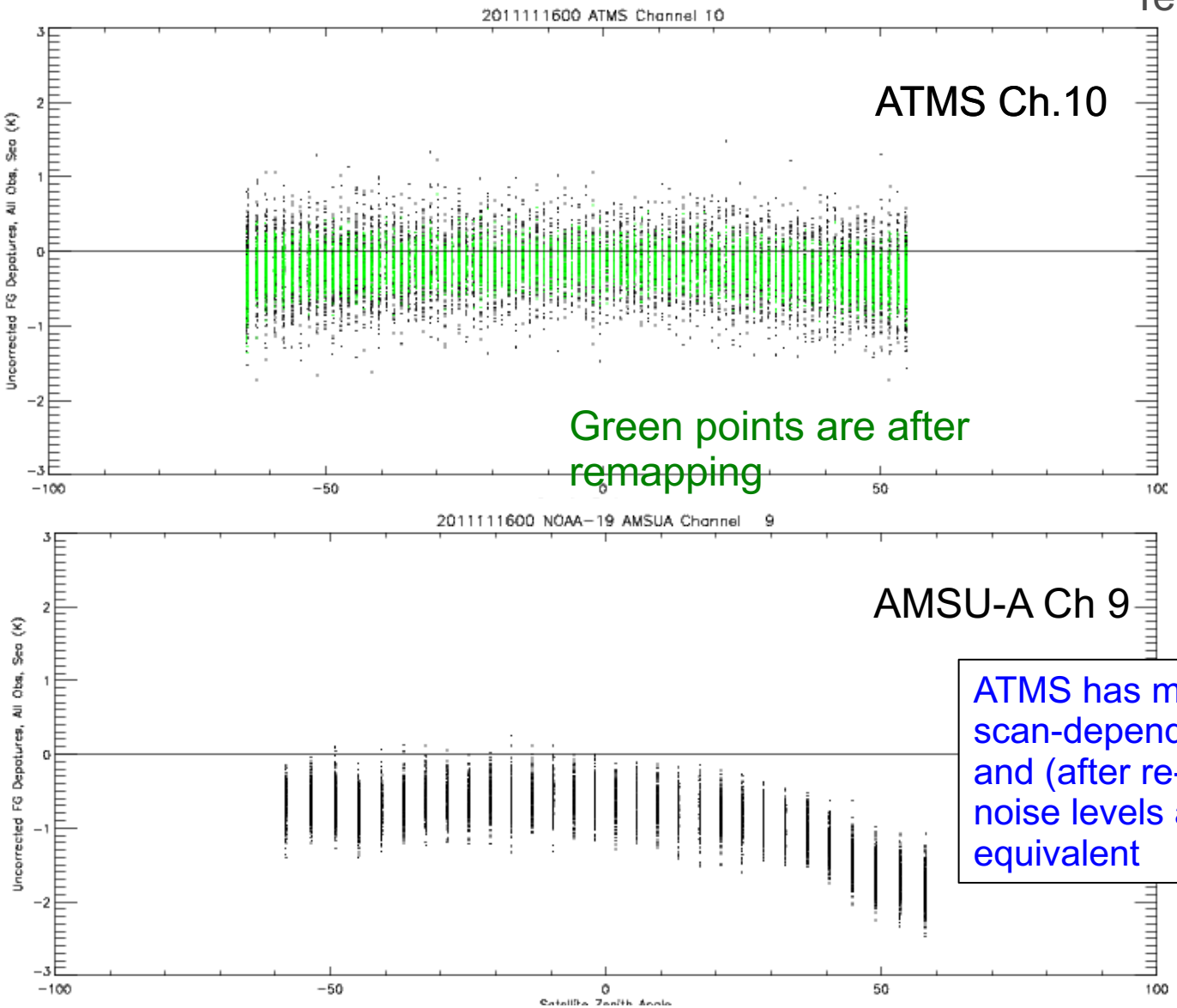


ATMS Spatial Averaging / Re-Mapping

- To produce noise characteristics similar to those of AMSU-A, we use the AAPP FFT-based remapping code to re-map (and in the process spatially average) the AMSU-A like ATMS channels to a common field of view (3.3°).
- This is to reduce the noise on the temperature sounding channels and also to allow the 5.2° FOV channels 1 and 2 to be consistent with the other AMSU-A like channels (as these are used for cloud-detection).
- Special attention has to be paid to missing and bad data as this will affect surrounding points in the re-mapped product.
- Similarly, we did not want to assimilate observations within 5 scan-positions/scan-lines of each other and they will be correlated.

AMSU-A vs ATMS Stats

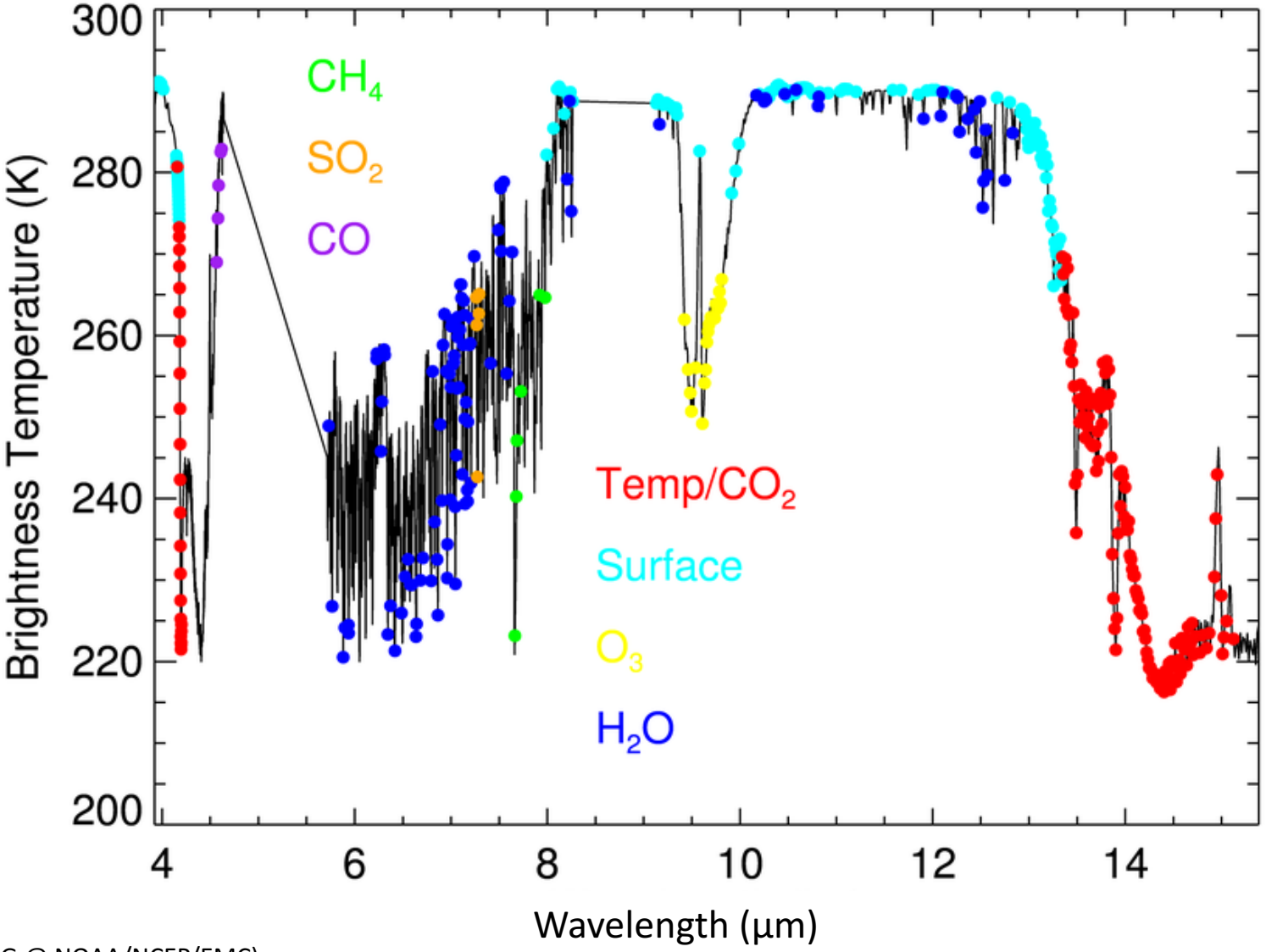
Antenna Temperatures



Uncorrected First Guess Departure; All Obs over Sea (K)

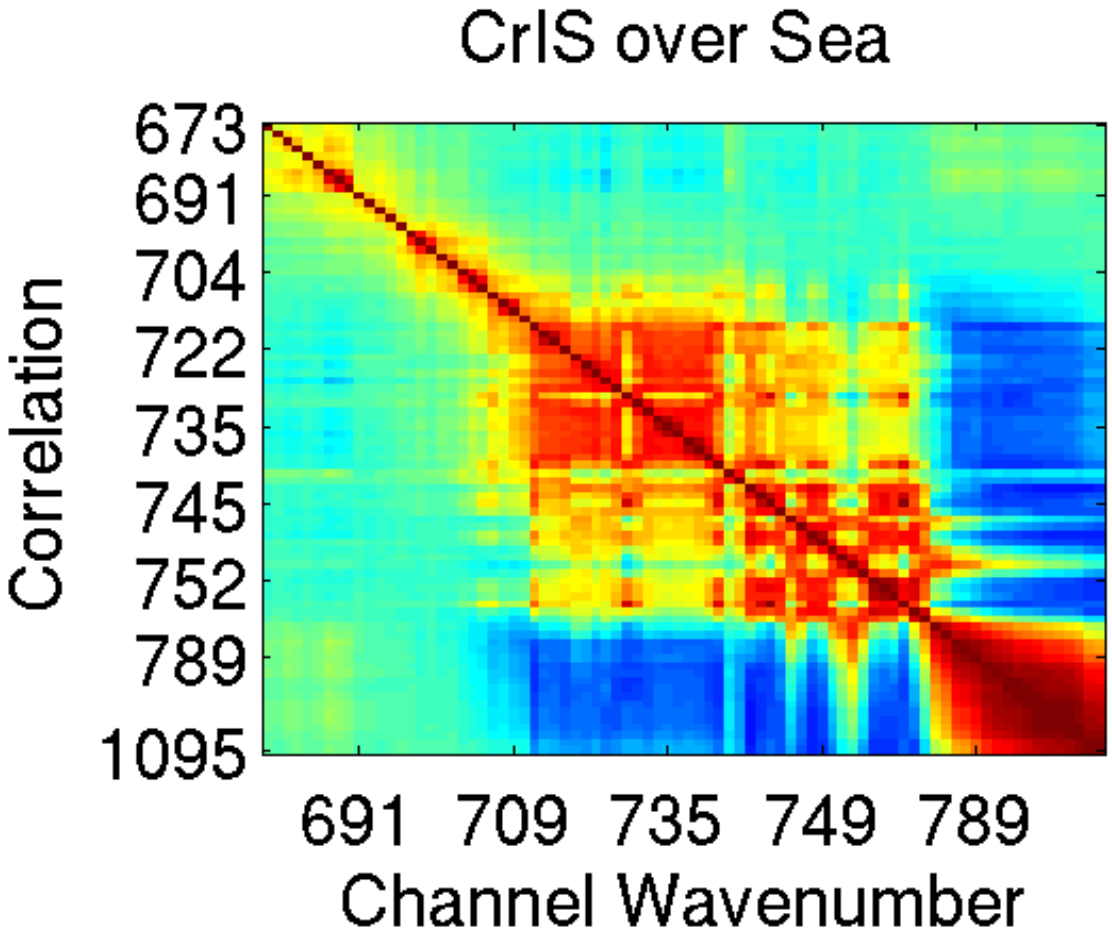
ATMS has much better scan-dependent bias and (after re-mapping) noise levels are equivalent

CrIS FSR Channel Selection



A. Collard (IMSG @ NOAA/NCEP/EMC)

CrIS Observation Error Correlation Matrix (Detail)



Strong adjacent-channel correlations due to apodisation …
In addition to significant broader correlation structures (forward model/representivity error?)

A. Collard (IMSG @ NOAA/NCEP/EMC)